Synthesis and Characterization of YBCO/LSMO composite

A thesis submitted for the partial fulfillment for degree of

MASTERS OF SCIENCE
IN
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BY

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CERTIFICATE

This is here to certify that the thesis entitled **"Synthesis and Characterization of YBCO/ LSMO composite "** by Bijayini Subhadarshini in partial fulfillment for the degree of masters of science in physics at National Institute of Technology, Rourkela is an authentic work carried by her under my supervision and guidance in low temperature laboratory of Department of Physics and Astronomy.

To the best of my knowledge, the matter embodied in this thesis has not been submitted to any other university/Institute.

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ACKNOWLEDGEMENT

Apart from my efforts the success of this project **“synthesis and characterization of YBCO/ LSMO composite”** depends largely on the encouragement and guidance of many others. I would like to express my gratitude and sincere thanks to my guide **Prof. D. Behera**, Department of Physics and Astronomy for his patience and helpful discussion during my project work. I truly appreciate and value his esteemed guidance and encouragement from beginning to the end of this thesis.

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ABSTRACT

YBCO is prepared by solid state route method and the purity and structure is confirmed from XRD and R-T measurements.. The resistivity temperature measurement is done by four probe method which gives T_{CO} at 91.35K. LSMO is prepared by sol-gel method and is added to YBCO to form a composite with different concentration to enhance the current density. The resistivity temperature of composites is done by four probe and an appreciable decrease in T_C is observed. Further studies can be carried out for the measurement of current density of composite.

CONTENTS

CHAPTER 1

1.1 INTRODUCTION TO SUPERCONDUCTIVITY

The electrical resistivity of certain material and alloys drops down to zero when the specimen is cooled to sufficiently low temperature. This phenomena was first observed by a Dutch physicist Heike Kamerlingh Onnes; In 1911 Kamerlingh Onnes assistants discovered the phenomenon of superconductivity while studying the resistance of a metal (Hg) at low temperatures.

The temperature at which the substance attains zero resistance, termed as critical temperature, T_c; below which SC have some interesting electric and magnetic properties such as the magnetic behavior shows perfect diamagnetism and high electric conductivity at superconducting state .

1.2 TYPES OF SUPERCONDUCTORS:-

Depending on their feedback to magnetic properties superconductors are classified into two types:

1.2.1 Type I or soft Superconductor:-

The type I superconductor are those for which Meissner effect is complete, that is perfectly diamagnetism. Below the critical magnetic field, if the magnetic field is gradually increased from its initial value the magnetization increases and at critical magnetic field the diamagnetism abruptly disappear, when the sharp transition from superconducting state to normal state takes place as shown in the figure.

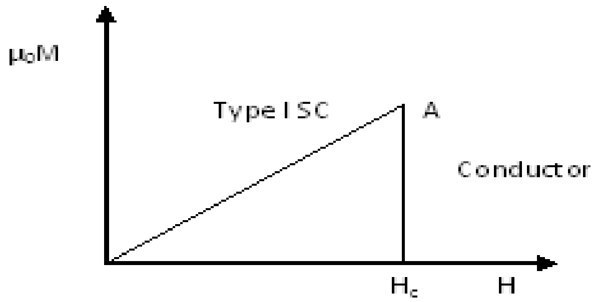


Fig. 1 Type I superconductor

1.2.2 Type II or hard Superconductor:-

Type II superconductor need larger field to come back to the normal state and called hard superconductor. When the magnetic field is increased from H = 0 to H_{c1} the lower critical value, the material behaves as a pure superconductor and the lines of flux are rejected. If H is increased further, the lines of flux are begin penetrating and the material is in a mixed state up to H_{c2} upper critical value. If H>H_{c2} , material comes to normal state and Meissner effect is incomplete at the region $H_{c1}\ to\ \ H_{c2}$.

- The region between the upper and lower critical value that is between H_{c1} andH_{c2} is called the vortex region or **vortex state**. After H_{c2} the superconductor become normal conductor.
- Type II superconductors are established as **hard superconductors** so they lose their superconductivity gradually but not easily.
- Type II superconductors carry out Meissner effect but not completely.

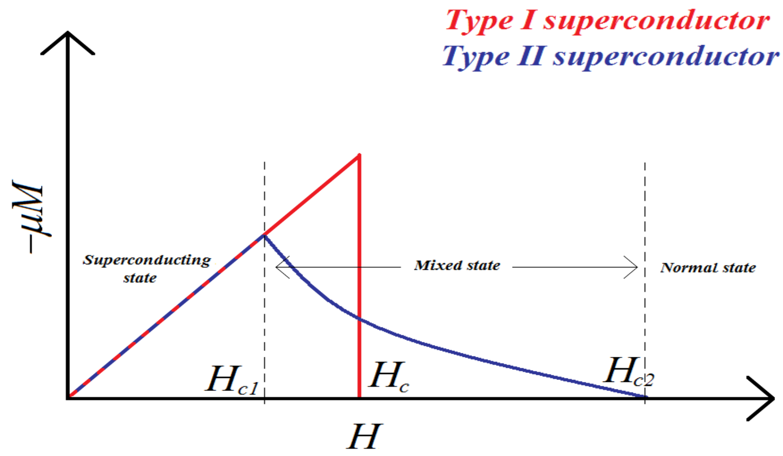


Fig 2. Type I and type II superconductor

1.3 PROPORTIES OF SUPERCONDUCTOR:

1.3.1 Zero resistivity: These having zero resistivity or we can say infinite conductivity at critical temperature. The critical temperature is a temperature at which the electrical resistivity of a material suddenly goes to zero. The transition is so spontaneous and complete that it appears to be a transition to a new phase that is superconducting phase.

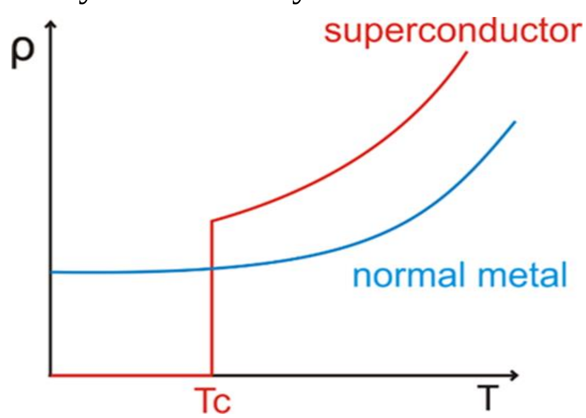


Fig 3 Resistivity graph

1.3.2 Effect of magnetic Field: If the temperature T of a specimen is raised above critical temperature the superconductivity disappears. It also vanishes if the magnetic field H is raised above critical magnetic field H_c, where the critical magnetic field depends on temperature. The superconductivity state becomes natural state when the magnetic field is greater than the critical magnetic field, even at absolute zero. Type II superconductor shows two critical values

If T = T_c , then H= 0.

If T < T_c , H_c increases , the variation of critical magnetic field with temperature is given by,

$$H_c = H_{c0} [1-(T/T_c)^2]$$

Where H_{c0} represents the critical magnetic field at 0K.

1.3.3 Entropy: We know entropy is a measure of disorder of thermodynamical system. Entropy of normal metals decreases with decrease in temperature. For superconducting metal entropy decreases up to T=T_C but when cooled below T_c the decrease in temperature is remarkable. The decrease in entropy between normal state and superconducting state shows that the superconducting state is more ordered than the normal state.

1.3.4 Energy gap: The energy gap of superconductor is completely different than the energy gap if insulator. In an insulator the energy gap is due to the electron lattice interaction. In superconductor the interaction is between electrons an electron which orders the electron in k space with respect to the Fermi gas of electron.

1.3.5 MEISSNER'S EFFECT: In 1933, Walter Meissner and Robert Ochsenfeld discovered a magnetic phenomenon which showed that superconductors are not just perfect conductors. When we apply a magnetic field, the superconductor will repels all the magnetic lines of flux, so the field B (H) inside the superconductor is zero. This effect is known as the Meissner effect.

When the applied temperature is less than critical temperature the magnetic lines of flux are rejected and the metal is a superconductor, when the temperature is greater than critical temperature the magnetic lines of flux will pass through the metal and it becomes normal conductor. Meissner effect is not a simple consequence of zero resistivity. For a perfect metal ($\rho = 0$), one can prove that the field inside must be a constant independent of time, but the field is not likely to be zero. In other words, superconductors are not perfect metals. The superconductors are the type of metal which expel all magnetic field lines.

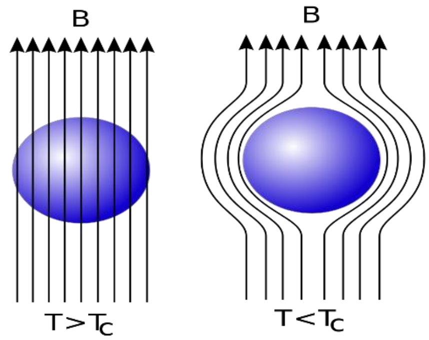


Fig 4 Meissner effect in superconductors

1.3.6 ISOTOPE EFFECT: If we measure the Tc of the same compound made by different isotopes, Tc has a strong connection to the isotopic mass M of the material.

M^{α} T_c = constant.

Where α is a constant, close to 1/2.

1.3.7 JOSEPHSON EFFECT: When two superconductors are separated by a very thin insulating layer, surprisingly, a continuous electric current appears, the value of which is related to the characteristics of the superconductors. This effect was concluded in 1962 by Brian Josephson. This sandwich of an insulator between two superconductors is called "Josephson junction". This effect has indication for superfast electrical switches which can be used to make small, high-speed computers and SQUID magnetometer.

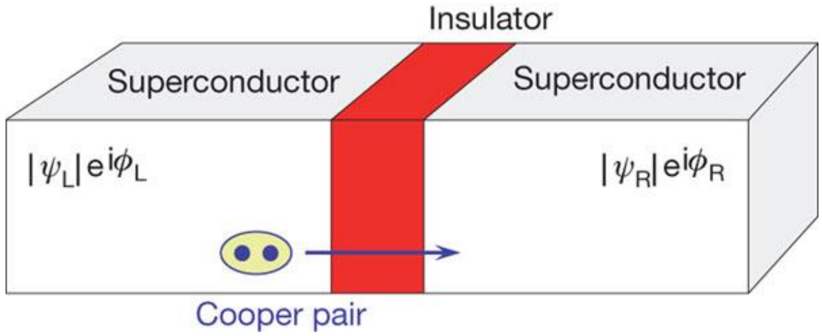


Fig 5 Josephson junction in two superconductors

1.3.8 FLUX QUANTIZATION: The total magnetic flux that passes through a superconductor may assume only quantized values, integral multiple of flux quantum $2\pi hc/q$, where $q=2e$, the charge of an electron pair. Beyond Hc_1, the field penetrates as quantized flux lines or vortices. The basic unit of flux vortex is one quanta of flux that is $\Phi = h / 2e$. A flux vortex comprises of a normal core of radius ξ enclosed by a superconducting region, where a supper current flows around the normal core to

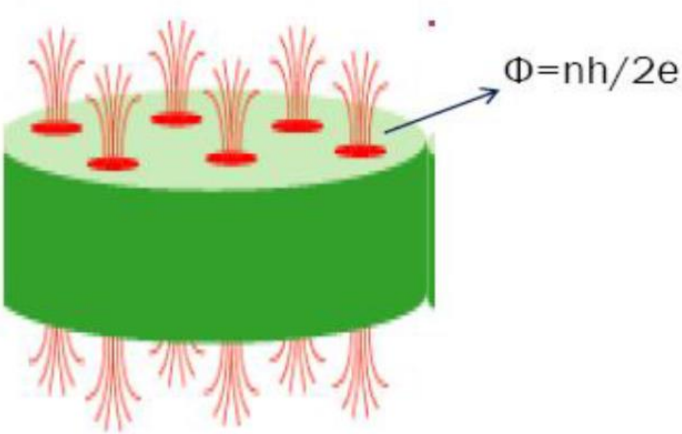


Fig 6 flux quantization in type II superconductor

produce the single quantum of flux Φ. This superconducting region is prolonged to distance λ that is penetration depth. The order parameter is zero inside the vortex.

1.3.9 PENETRATION DEPTH: Two scientists F. London and H. London described the Meissner effect and zero resistivity by adding the two condition E= 0 from the absence of resistivity and B= 0 from Meissner effect to Maxwell electromagnetic equation. According to them the applied magnetic field does not sharply drops to zero at the surface of the superconductor, but it decays exponentially according to the equation,

$$H = H_0 \exp(-x/\lambda)$$

Where H_0 is the magnetic field at the surface and λ is a characteristics length known as the penetration depth; λ is the depth of the penetration of the magnetic field.

1.3.10 BARDEEN-COOPER-SCHRIFER (BCS) THEORY:

The BCS theory contains the following

1. The electron in the superconducting state form bound pairs (the Cooper pair), the interaction between electron and lattice, through lattice vibration, leads to electron– electron interaction forming bound electron pairs.
2. By the exchange of virtual phonons between two electrons, a bound electron pair formed termed as Cooper pairs. An electron with spin up and momentum (k) pairs with another electron with spin down and momentum (-k) so that the angular momentum of the system is zero.
3. A small amount of energy is needed to destroy the superconducting state and turn it normal. This energy is labeled as the energy gap.
4. The energy gap corresponds to the binding energy and the coherence length is the same as the size of the electron – pair.

BCS theory had a good agreement with the properties exhibited by the superconductors such as

- It describes the variation of the critical magnetic field with temperature etc

- BCS theory correctly predicts the Meissner effect, i.e. the ejection of a magnetic field from the superconductor and the variation of the penetration depth with temperature.

1.4 High T_c SUPERCONDUCTOR:

Superconductors, especially High Tc Superconductors'(HTS) having the fascinating property of carrying zero resistance and hence, applicability in power transmission, medicine and in accelerators etc. and lacking of accurate theory to explain the phenomena of HTS draws considerable attention of physicists' to explore the theory as well as more and more practical implication of it. Due to the less applicability of elemental superconductors which has transition temperature less than liquid nitrogen boiling temp. (77K) scientist's think to develop HTS and pioneer to it, the discovery of YBCO (Tc = 93 K) by Georg Bednorz and K. Alex Müller led foundation to HTS. After that, the next year itself development of BSCCO discovered with Tc up to 108 K, and TBCCO (T=thallium) having Tc of 127 K add stuffs to it. The highest-temperature superconductor (at ambient pressure) is mercury barium calcium copper oxide (HgBa2Ca2Cu3Ox), at 135 K is found to have highest Tc. Despite of discovery of these cuprate superconductor's having high Tc there is lacking of theory to explain the physics behind it because BCS theory is only valid up to Tc $\leq$ 30 K and not beyond it; but yet some models have developed to give the possible mechanism origin of HTS such as interlayer coupling model and spin fluctuation model (d-wave symmetry).However, in spite of lacking theoretical background, the research has never been stopped in HTS due to their versatility in applications' ;starting from high power transmission cable's to constructing large magnets in LHC and high speed Maglev train's.

PROPORTIES OF HTSC:

1. The HTSC have their structure like perovskite structure.

2. They have layered like crystal structure consist of one or more CuO_2 planes.

3. In superconducting plane charge transformation can take place which is controlled by the insulating layer and charge conserver.

4. Small coherence lengths, large penetration depth, higher T_c. large energy gap are the common properties of high temperature superconductivity.

1.5 APPLICATIONS OF SUPERCONDUCTORS:

Superconductors are already used in many fields of study like electricity, astrophysics, electronics, medical applications and even trains. Their use have been found in scientific laboratories, particularly in particle accelerators, in SQUIDs which is ultrasensitive magnetic detectors, and in superconducting coils to create very strong magnetic fields. However, superconductors need to be cooled to very low temperatures, is a cause of restriction of daily use. If we discover new superconducting materials that do not require any cooling that will enhance the use of superconductors. That discovery may bring revolution in energies environment, transportation and computer science.

- Manufacture of sensitive magnetometers established on SQUIDs.
- High power superconducting electromagnets are used in maglev trains, Magnetic Resonance Imaging (MRI), Nuclear magnetic resonance (NMR) machines, magnetic confinement fusion reactors, and the beam-steering and focusing magnets which are used in particle accelerators.
- RF and microwave filters, military ultra-sensitive/selective receivers.

- High sensitivity particle detectors, the superconducting bolometer, the superconducting tunnel junction detector, the kinetic inductance detector, and the superconducting nanowire single-photon detector.
- Superconducting generator.
- Superconducting magnetic energy storage.
- Superconducting transformers.
- Superconducting filters.
- Magnetic levitation.

FLUX CREEP, FLOW AND PINNING: Superconductors are diamagnetic, so repels magnetic lines of force completely until the magnetic field is H_{c1}. When the magnetic field is increased further, the magnetic lines of flux starts penetrating into the superconductor in the form of vertices. When the field strength is increased more number of magnetic flux penetrates into it until H_{C2}. This happens only in homogeneous Type-II superconductors which are associated with flux-line lattice (FLL). Each FLL carries a quanta of flux (Φ) which is characterized by the presence of a normal core. But in case of an ideal homogeneous defect less superconductors, the flux lines are not pinned and as a result the critical current density Jc vanishes. The interaction of the FLL with various crystal imperfections, pinning centers in Type-II superconductors are responsible for the existence of a critical current density Jc, usually defined as the current density at which an arbitrarily small voltage is observed. When a magnetic field penetrate into the superconducting region, it creates an electric field.

Along with both the electric and magnetic field vertices experience Lorentz force, which is

$$F_L = J_C \times \mathrm{B}$$

Where, J_C is the amount of current in the sample, B is the magnetic field

So the vertices starts to move in the mixed state region. When flux lines moves it experiences a force called viscous drag force F_v which opposes the motion of flux lines that is ηV_l inside the medium, where V_l the vertex velocity and η is constant of proportionality. The viscous force balances the driving force per unit length of vortex line. When there is no pinning,

$$J_C \times \mathrm{B} = \eta V_l$$

$$\text{So,} \quad F_L = J_C \times \mathrm{B} - \eta V_l$$

When the Lorentz force disables the viscous force, the flux lines starts moving. When the vertices moves the resistance of the sample increases therefore the current density J_C decreases. So we have to discontinue the vertex movement, there by enhancement of J_C by introducing some form of pinning force. This pinning force is introduced through the addition of pinning centers or defects which acts as a potential well where the vertices will become trapped or pinned. Pinning arises in the form of any inhomogeneity in the materials such as, impurities, grain boundaries or voids. These can be done through doping and impurities. It can be also done through different types of microstructural in homogeneities, like dislocation, inter- and intra- grain boundaries precipitation of secondary phases. The artificial pining centers are the very suitable for superconductors.

High temperature superconductor (HTSC) of granular shapes have grain boundaries. These grain boundaries acts like pinning centers and prevents vortex motion, by addition of appropriate microscopic impurity to high temperature superconductor. So composite of nano particles of metal, insulator and oxides are very exciting in HTSC for creating pinning centers. From literature, it is determined that out of all, magnetic nano inclusion are more advisable to increase Jc. As LSMO behaves as half metal and act as a good barrier layers in superconducting-ferromagnetic-superconducting hetero structure, so for effective pinning center, it is useful. [5]

1.6 MOTIVATION FOR CHOOSING SAMPLE:

After reviewing the earlier literatures, as for enhancement of critical current density, we need crystalline defects, artificial pinning centers etc. and as the effect of addition of nano particles as a pinning center attributes to a quiet impress able enhancement of J_c. So here we choose to add different conc. of $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) to analyze its effect on different parameters such as T_c and J_c of it in YBCO matrix.

CHAPTER 2

LITERATURE

2.1 YTTRIUM BARIUM COPPER OXIDE (YBCO):

Yttrium barium oxide often abbreviated YBCO, is a family of crystalline chemical compound famous for "High-temperature superconductivity". It is one of the very early materials discovered to become superconducting above 77K which is the temperature at which nitrogen liquefies. The YBCO superconducting material was discovered in 1987 which brought a great excitement within the community of science. The property of conducting electricity without resistance, at temperatures above 77 K, increases the possibility for several progressions in electronics and wire technologies. YBCO was the first crystalline material having transition temperature at 92K.The general formula for YBCO is $YBa_2Cu_3O_{7-x}$ .The superconducting properties of $YBa_2Cu_3O_{7-x}$ are depends on the value of x, the oxygen content. Only those materials with $0 \leq x \leq 0.65$ are superconducting below Tc, and when $x \sim 0.07$ the material super conducts at the highest temperature of 95 K or in highest magnetic field.

2.1.2 STRUCTURE OF YBCO

YBCO crystallizes in a defect perovskite structure comprising of layers. The boundary of each layer is defined by planes of square planar CuO_4 units sharing 4 vertices. The planes can sometimes be slightly wrinkled.Vertices are shared perpendicular to these CuO_2 planes and CuO_4 ribbons . The yttrium atoms are seen between the CuO_2 planes, between the CuO_4 ribbons and the CuO_2 planes the barium atoms are seen . The dimensions of a single unit cell of YBCO are a = $3.82A^0$, b = $3.89A^0$and c = $11.68A^0$. The lattice consists of so-called perovskite layers (ACuO3) where A is a rare-earth or alkaline-earth element

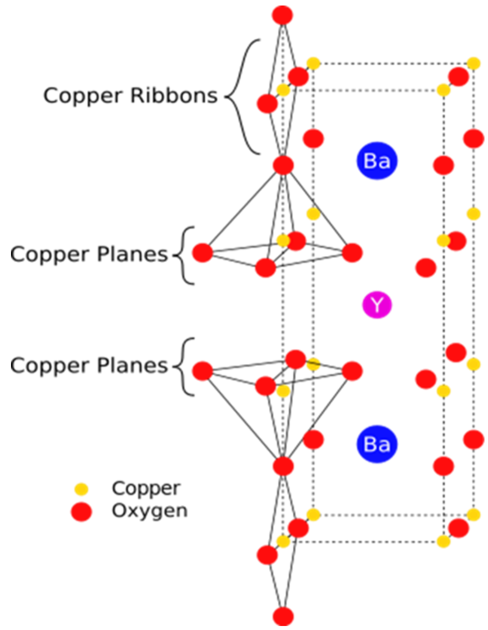


Fig 7 structure of YBCO

(e.g. or Ba in YBCO). The term 7-x in the chemical formula suggests a slight lack of oxygen. If x =0, the lattice is in the orthorhombic phase whereas in the situation of x=1, the material has a tetragonal structure and it will be a semiconductor. Its penetration depth is of 120 nm along ab plane, 800 nm along the c axis and have coherence length of 2 nm in the ab plane, and 0.4 nm along the c axis.

2.2 LSMO

It is an antiferromagnetic insulator when we dope strontium with it, there is a metal insulator transition and ferromagnetic transition in it at Tc and Tp correspondingly. Strontium doped lanthanum manganite (LSMO) is an oxide ceramic material having general formula

$La_{1-x}Sr_xMno_3$ where x is the doping level of strontium.

LSMO is a half metal with manganese configuration Mn^{3+} and Mn^{4+} which gives rise to a metallic state of negligible spin polarization at Fermi level. The band theory describes the electrical property of LSMO which reveal the half metallic behavior. LSMO behaves as a metal and ferromagnetic below the curie temperature, due to this property LSMO is used as barrier layer in high temperature superconductors.

2.2.1 STRUCTURE OF LSMO

It has a perovskite based crystal structure which has the general form ABO_3.In the crystal the ‘A’ sites that is the corner of cube are occupied by lanthanum and strontium atom andat the ‘B’ site the body center is there is presence of the Mn atom and all the face center are occupied by oxygen.

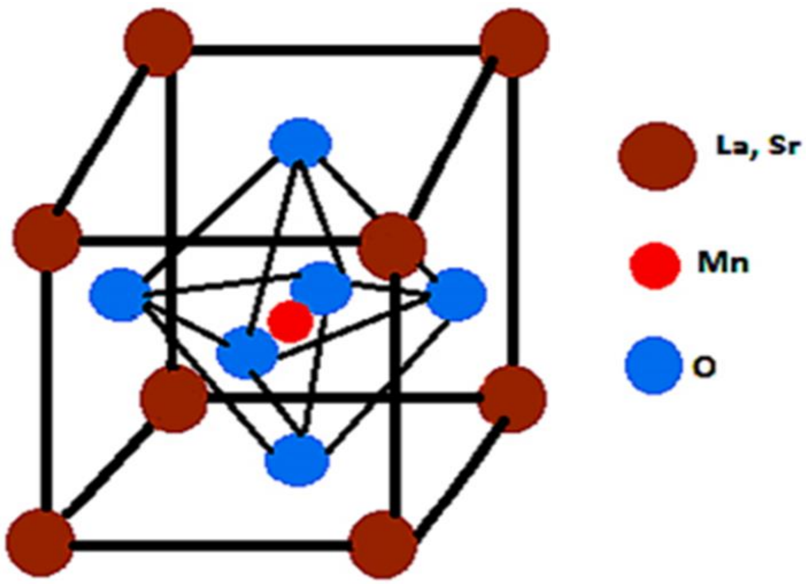


Fig 8 structure of LSMO

CHAPTER 3

SAMPLE PREPARATION:

3.1 Preparation of YBCO:

High temperature superconductors are generally prepared by solid state route method. For the preparation of YBCO the precursor powders were taken as Y_2O_3, $BaCO_3$, and CuO.

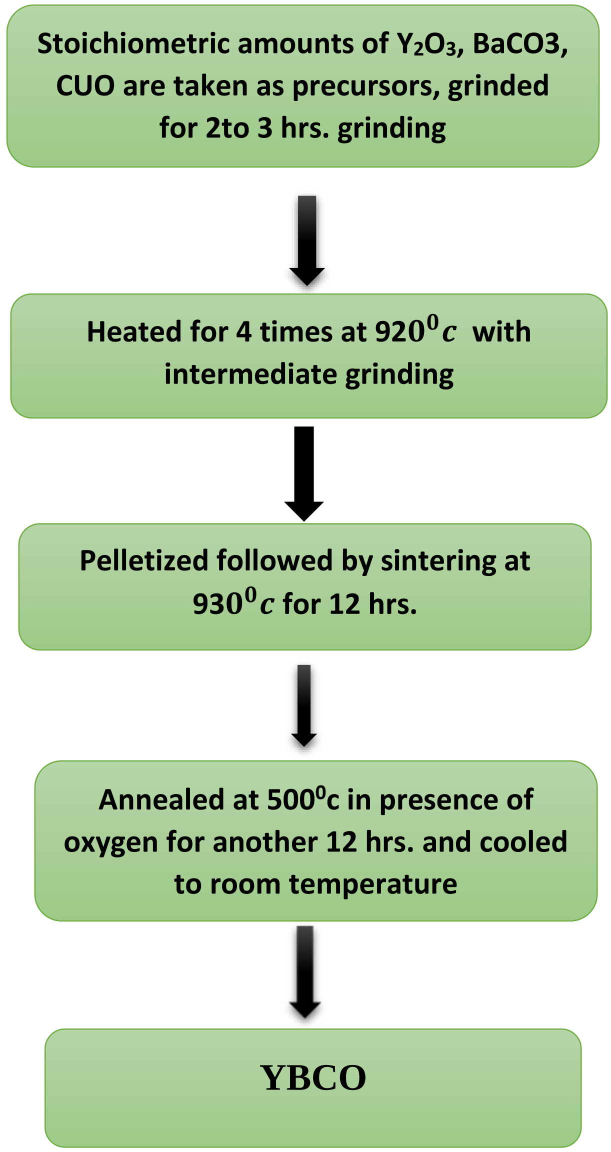
YBCO was arranged by mingling the chemicals as per the balanced chemical (

$$\frac{1}{2} Y_2O_3 + 2\, BaCO_3 + 3CuO + \frac{1}{2}O_2 \longrightarrow YBa_2Cu_3O_{7-x} + 2CO_2 \uparrow$$

The following steps are involved for the sample preparation.

Yttrium oxide, Barium Carbonate and Copper Oxide was taken in stoichiometric ratio for the preparation of YBCO. The raw materials were measured using the high precision weighing machine. The mixed sample was taken and was thoroughly grinded in agate mortar for 2 to 3 hour so as to obtain a mixed powder. The sample was calcined at 920°C for 12 hours for 4 times followed with intermediate grinding each time. The mixtures were taken out after the temperature reached to room temperature. For sintering pellets were made by pelletizer with a pressure of 100MPa. The YBCO pellets were sintered at 900°C for 12 hours, in normal atmosphere and 6 hours in the presence of oxygen.

3.1.2 FLOW CHART FOR YBCO PREPARATION



3.2 PREPARATION OF LSMO:

There are so many conventional methods are present for the preparation of LSMO. It can be prepared by following methods;

- Sol-gel method.
- Solid state route method.

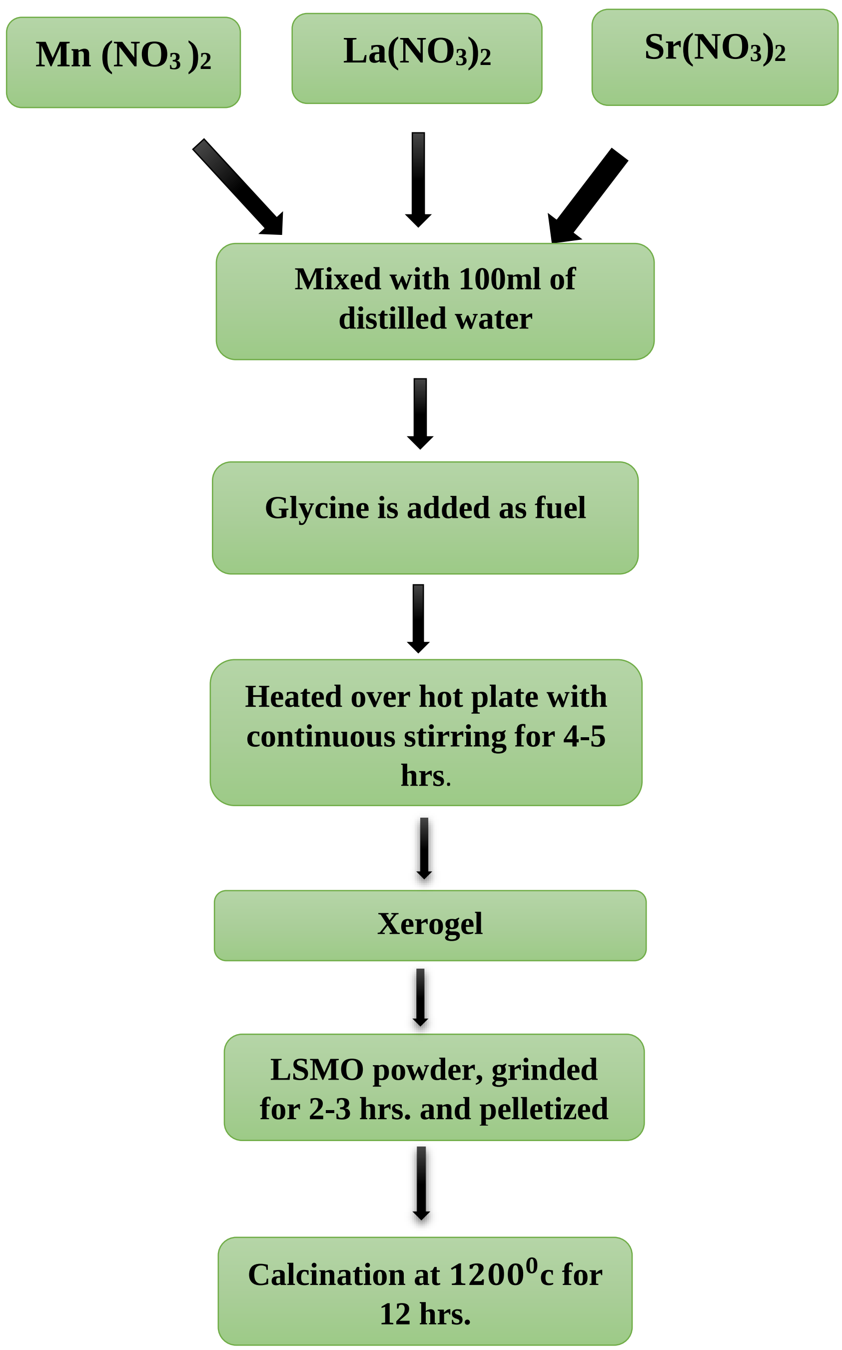
- Pulse laser deposition method.
- Float zoning method.
- Spray dryer method.

Among of all these route I have chosen the sol-gel method for the preparation of LSMO. In this the constituents of LSMO are mixed at atomic level after that the lattice growth occurs. The main advantage of using sol-gel combustion method for the synthesis of samples is that we can found less impurities and small grain size particles.

PROCESS INVOLVED

The composite material $La_{0.7}sr_{0.3}MnO_3$ is synthesized by sol-gel combustion route method. Mn $(NO_3)_2$, Lanthanum nitrate $La(NO_3)_2$, Strontium nitrate (Sr (NO_3)2) are taken as the constitutes for the synthesis of LSMO. The fuel for the synthesis is Glycine. All the materials along with glycine are taken according to the stoichiometry calculation and are mixed with 100 ml of distilled water in a beaker. Then the solution is heated on a hot plate slowly with continuous stirring. After 4-5 hours of this heating a gel is formed due to evaporation of water without precipitation. A vigorous combustion reaction occurs after 30 minutes and the gel is burnt which gives a black powder. The black powder is collected and grinded for 2-3 hours followed by calcination for 5 hours at temperature 820^0c. The sample is taken out from the furnace and used for the characterization.

FLOW CHART FOR LSMO PREPARATION



3.3 PREPARATION OF COMPOSITE OF YBCO/LSMO

To make the composite, LSMO of different wt% (2,5,10) is added to YBCO matrix; followed by 2 hours of grinding and then pelletized . The obtained pellet is then put in to the furnace for 12 hrs. at 930^0C for sintering. The sintered sample is taken out and then used for various characterization.

CHAPTER 4

CHARACTERISATION TECHNIQUES

4.1 XRD (X-RAY DIFFRACTION) ANALYSIS:

When an electron beam incident on a metal this incident electron knock out one electron from the inner shell and a vacant space or hole is created there. To fill this hole an electron from the outer shell jumps to the vacant place, during this transition large amount of energy is released this energy comes out as x-ray beam. This technique is

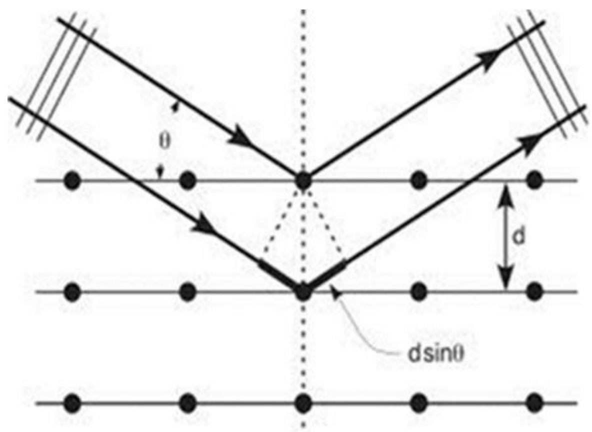
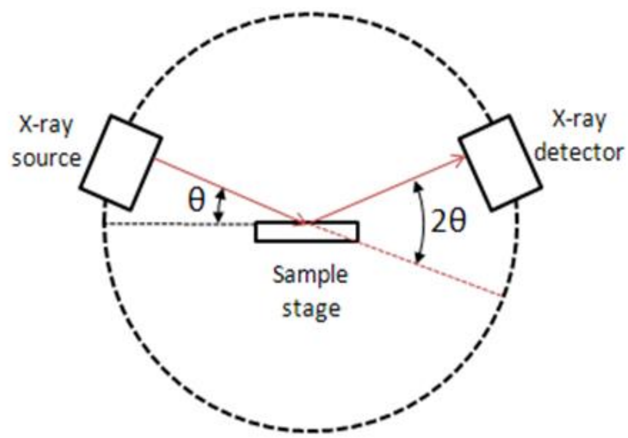


Fig 9 Braggs diffraction

based on the principle of Bragg's diffraction. In which Bragg described that when a monochromatic parallel x-ray beam of wavelength 'λ' incident on a crystal at angle 'Θ' ,the beam is diffracted by the parallel planes of the crystal. So the Bragg's diffraction condition is given by

$$2d\sin\Theta = n\lambda$$



This is used to identify the structures of crystalline solids. The XRD patterns are unique to each material. The data in a XRD pattern gives the idea directly from two things; the shape and size of the unit cells, which determines the relative positions of the diffraction peaks. the atomic position of the unit cell is given by the relative intensities of the diffraction peaks. The X-ray diffractometers basically consist of three elements: an X-ray tube, a sample holder, and an X-ray detector. X-rays are produced in a cathode ray tube by heating a filament electrons are produced, these electrons are accelerated toward a target by applying a voltage , and bombarding the target material with electrons. When electrons get sufficient energy to knock out inner shell electrons of the target material, characteristic X-ray spectra are generated. when the sample and the detector rotates, the intensity of the reflected X-rays is recorded. When the incident X-rays falling on the sample satisfies Bragg's Equation, constructive interference occurs and a peak in intensity arises. A detector collects and processes this X-ray signals and converts the signal to a count rate which is projected on the computer screen.

4.2 R-T MEASUREMENT

The electrical resistivity of a material depends on its nature. It is calculated by measuring resistance R and the dimension of the sample such as width, length, thickness etc. The resistance of a material is determined by the voltage –current value. When a current of known value is supplied to the sample, then a potential difference occurs across the resistor which gives us the resistance value. i.e

R = V/I . So the resistivity is calculated as,

$$\rho = R \times A/L$$

R is the electrical resistance of the material

L is the length of the material

A is the specimen's cross sectional area

There are mainly two types of techniques that are used for the measurement of resistivity. Two probe or four probe technique can be used for the measurement of resistivity.

4.2.1 Two probe method: For a long wire like geometry of uniform cross section or for a rectangular shaped sample of uniform cross section, by measuring its voltage drop across the sample due to passing of constant current through the sample the resistivity ‘ρ’ can be measured.

The battery supplies the current which is measured by the ammeter. In the case of two probe method only one pair of leads goes to the sample from RT instrument, in this case the voltmeter and current source share the same pair of leads. The major problem in this method is their will be an error due to the contact resistance that is their will be a voltage drop so we cannot get an accurate voltage.

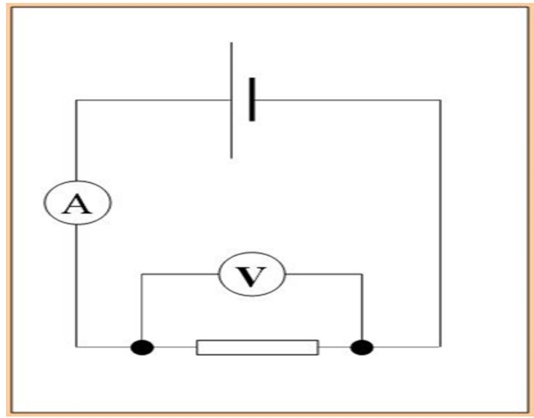


Fig 11 Two probe technique

4.2.2 Four probe method:

The advantage of for four probe method is that it minimizes the other contributions like lead resistance, contact resistance, etc. to the resistance measurement, which gives an accurate result in the measurement of sample resistance. In this four probe method four equally spaced probes are used which are in contact with a material.

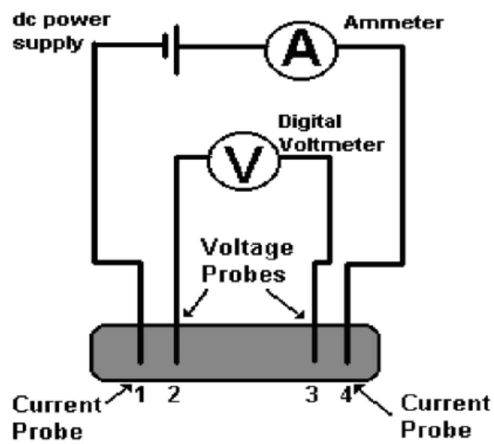


Fig 12. Four probe method.

The outer two probes are used for sourcing the current and two inner probers are used for measuring the resulting voltage drop across the surface of the sample. A high impedance current source is used to supply current through the outer probe to the sample. A voltmeter measures the voltage across the two inner probes to determine the sample resistivity. These inner probes draws no current due to the presence of high input impedance voltmeter in the circuit. The unwanted voltage drop at point 2 and 3 due to contact resistance between probes and sample is eliminated. The two inner probes measures the potential difference.

CHAPTER 5

RESULT ANALYSIS

XRD ANALYSIS:

The diffraction pattern of YBCO sample prepared by solid state route method is studied by XRD characterization. The phase is confirmed as orthorhombic. Appearance of peaks in the pattern exposes the orientation and purity of the sample. The diffraction data matches well with JCPDS file no- 39-0486.

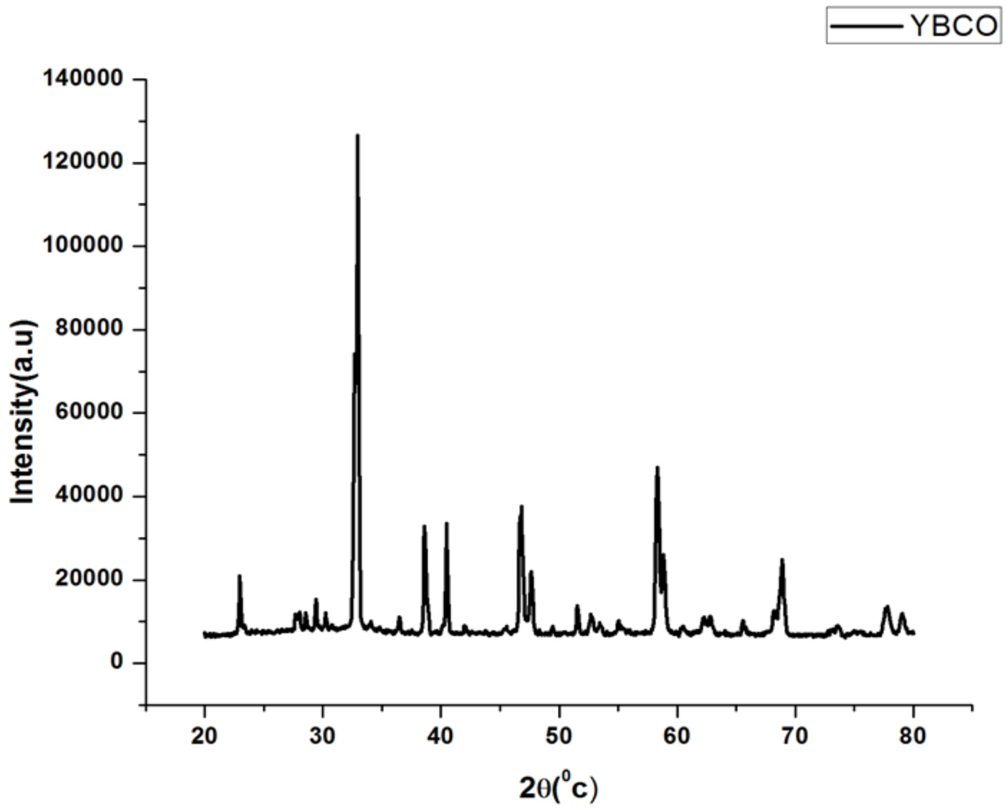


Fig 13. XRD pattern

XRD ANALYSIS OF YBCO/LSMO COMPOSITE

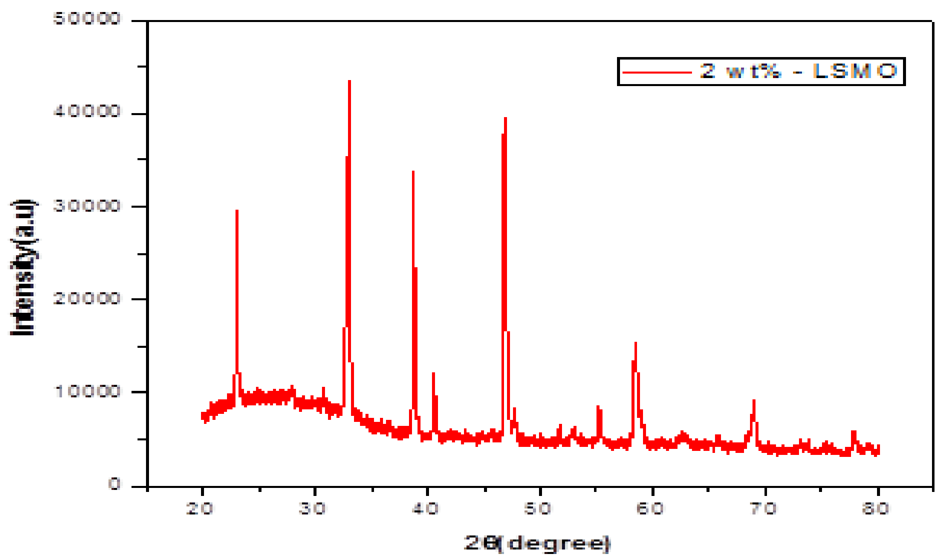


Fig 14. 2 wt% of LSMO

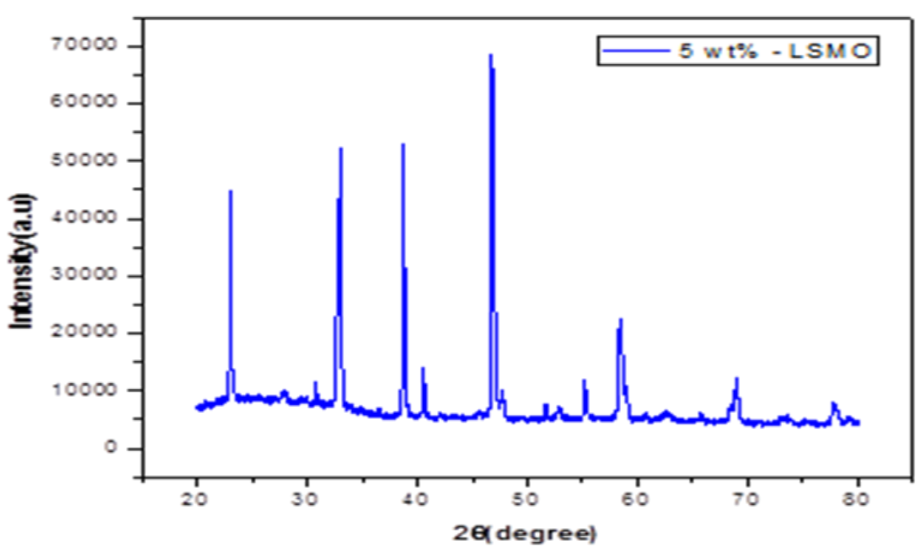


Fig 15. 5 wt% of LSMO

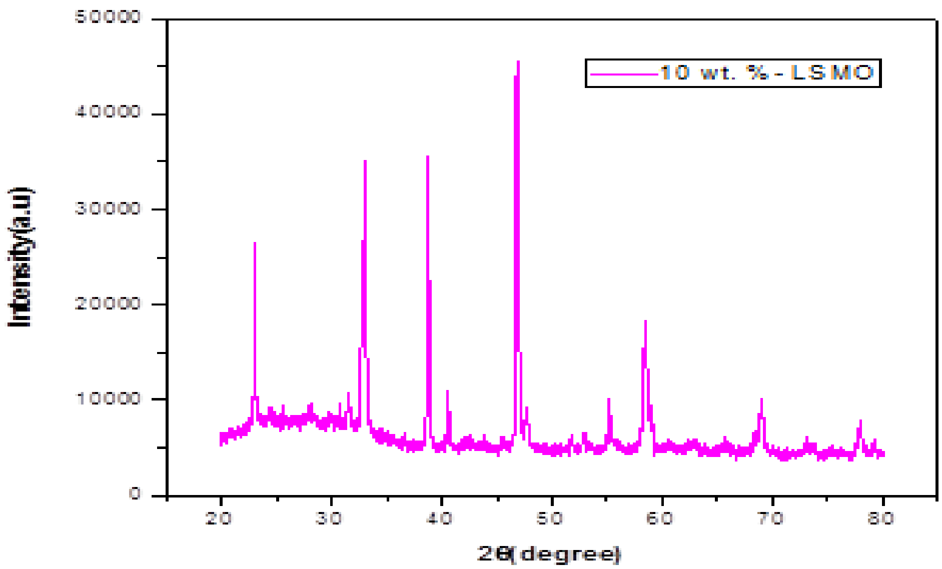


Fig 16. 10 wt% of LSMO

By analyzing the XRD pattern of YBCO/LSMO composite, the purity and the formation of three composite sample is confirmed.

R-T MEASUREMENT ANALYSIS:

By using the standard method i.e. four probe method the resistivity measurement is done. In this technique, by using highly conducting silver paste the four probes are connected to the sample which is mounted inside the cold head (sample holder). For pure YBCO when we analyzed the graph, it shows to regions; the linear region above T_C and the region of nonlinearity below T_C. The linear region shows the metallic behavior and the nonlinearity region represents the presence two kind of charge carriers superconducting electrons and normal electrons i.e. the superconducting region. In case of YBCO the onset of superconductivity starts at (T_{CO}) around 91.35K (fig 18). From this temperature the metal phase changes to a superconducting phase. When different concentration of LSMO is added to the parent material YBCO the resistivity of the composite material decreases by the addition of different concentration of LSMO. By adding 2 wt% of LSMO to YBCO the critical temperature decreased. We got two transitions first i.e $T_{CO}(1)$ comes at 85.47K which is due to the YBCO phase and the second one i.e. $T_{CO}(2)$ at 73.23k which is due to the LSMO(fig19). And for the higher wt % addition of LSMO i.e.adding 5 wt% of LSMO to YBCO we observe a clear declinement of transition temperature . i.e. $T_{CO}(1)$ comes at 41.83K which is due to YBCO phase and another comes ($T_{CO}(2)$) at 22.89K is for LSMO phase(fig 20). And for 10 wt% addition of LSMO; we found that, the superconductive property is completely lost and the sample is becoming a purely semi-conducting one with a transition from metal to semi-conductor at 66.80K shown in the fig 17.

R-T MEASUREMENT OF YBCO

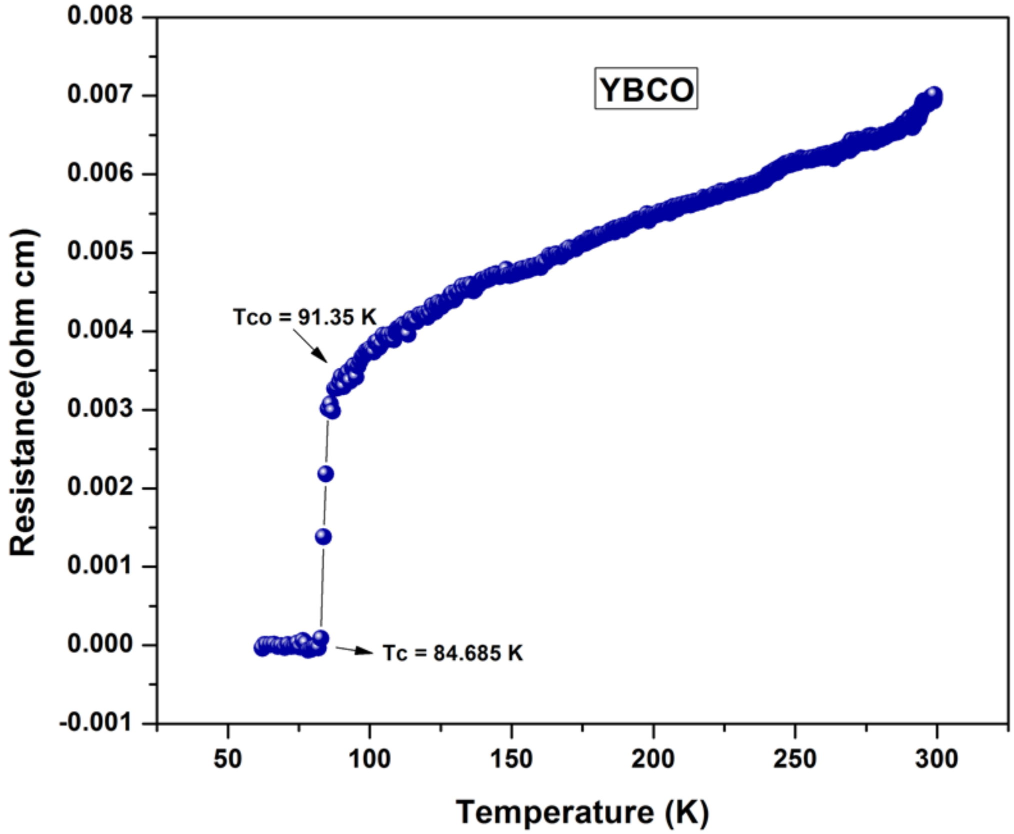


Fig 17. R-T of YBCO

R-T MEASUREMENT OF COMPOSITE

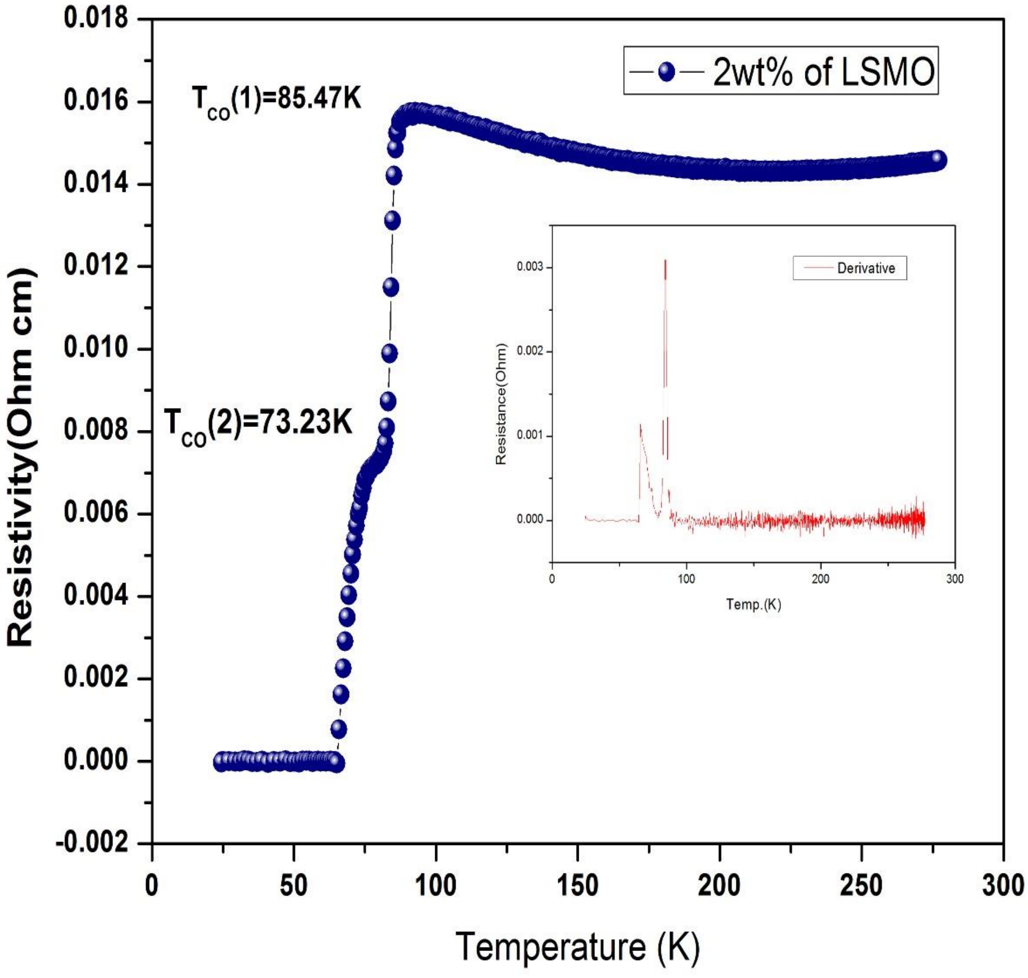


Fig 18. R-T OF 2 WT% LSMO

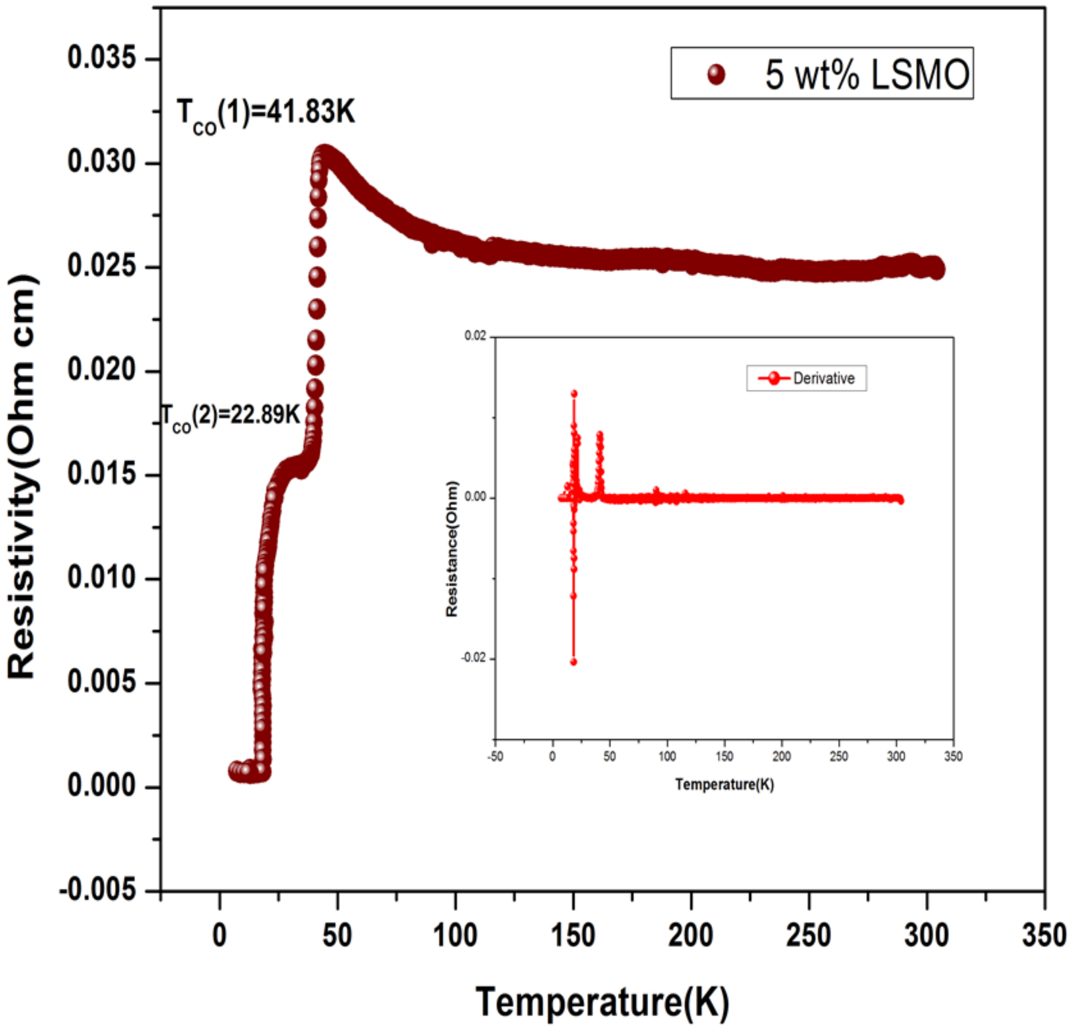


Fig 19. R-T of 5 wt% of LSMO

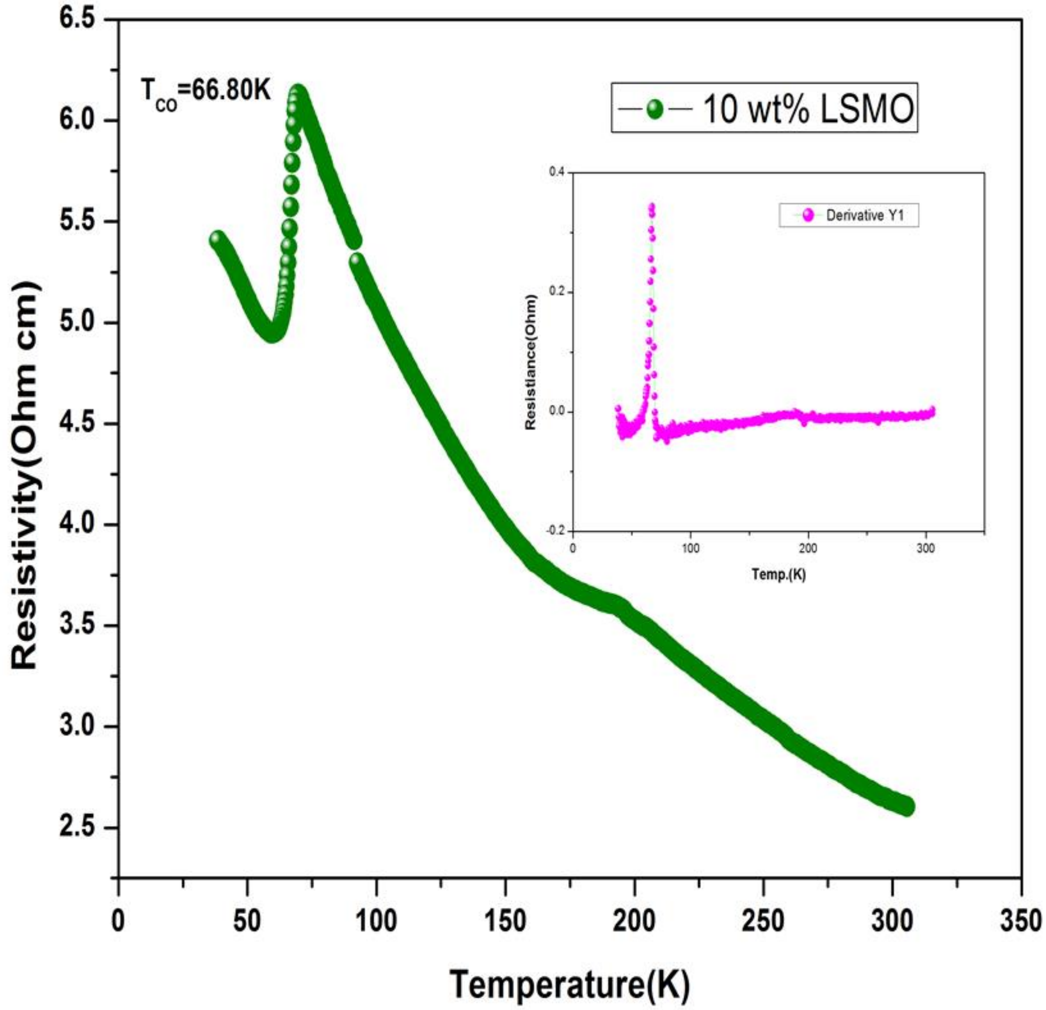


Fig 20. R-T of 10 wt% of LSMO

CHAPTER 6

CONCLUSION:

From the XRD analysis the phase formation of YBCO sample is confirmed. The phase formation analysis reveals the formation of superconducting phase with Tc ~ 91.35 K measured by four probe technique. Composite of YBCO/ LSMO is synthesized and various characterization are done by adding difference concentration of LSMO (2,5,10 wt.%) .The purity of the composite material is confirmed from the XRD analysis. By doing R vs. T measurement of the composites it is found that the T_C decreases as we increases the concentration of LSMO in composite. For high wt.% of LSMO the composite becomes a metal - semiconducting phase. Further studies can be extended for the measurement of critical current density.

BIBLIOGRAPHY

1. Knizhnik, A (2003). " Physica C: Superconductivity.
2. Introduction to solid state physics by C. Kittle.
3. Introduction to solid state physics by S.P. Kuila.
4. “Solid state physics” – S.O. Pillai
5. K. M. Wu et al. (1987). "Superconductivity at 93ÄK in a new mixed-phase Y-Ba-Cu-O compound system at ambient pressure". Physical Review Letters 58 (9).
6. P Gennes (1989). Superconductivity of metals and alloys.
7. http://www.physics.usyd.edu.au/~khachan/PTF/Superconductivity.pdf
8. http://www.researchgate.net/publication/225172473_Superconductivity and Magnetisms.
9. http://www.ukessays.com/essays/engineering/the-electrical-resistance of material.
10. Superconducting gap structure and pinning in disordered MgB films. (n.d.). Retrievedfromhttp://www.researchgate.net/profile/O_Dolgov/publication/1780255_Superconducting_gap_structure_and_pinning_in_disordered_MgB2_films/links/0fcfd50f14ea872791000000.pdf.
11. http://adsabs.harvard.edu/abs/2011JPCM...23w4109A.
12. http://en.wikipedia.org/wiki/Yttrium_barium_copper_oxide.
13. http://www.yale.edu/ynhti/curriculum/units/1983/7/83.07.03.x.html.
14. http://www.geobib.lu.se/publikationer/geologi/abstract/238abs_g.html.
15. http://www.tpub.com/neets/book1/chapter1/1o.htm.
16. http://www.worldclasscad.com/mechanical_pdf/ch%2012%20compression%20spring.pdf
17. http://www.keithley.com/data?asset=15222